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A FLIGHT INVESTIGATION OF THE STABILITY OF A TOWED BODY

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

A FLIGHT INVESTIGATION OF THE STABILITY OF A TOWED BODY

By W. H. Phillips

SUMMARY

At the request of the Bureau of Aeronautics, a towed body was designed and built to meet certain specifications of size, weight, and stability. Flight tests were made to determine whether the body met the stability specification, which required that angular deviations in flight should be less than $\pm 1^\circ$. This requirement for stability was met in flight in smooth air, where pitching and yawing oscillations of $\pm 0.4^\circ$ and rolling oscillations of $\pm 0.8^\circ$ were measured. In rough air angular deviations in pitch and yaw were somewhat larger than those specified, and rolling motions were considerably larger.

INTRODUCTION

The Bureau of Aeronautics required a towed body capable of containing certain instruments that have the external dimensions shown on figure 1. It was desired that the body should deviate from a fixed position less than $\pm 1^\circ$ in pitch, roll, or yaw while in flight, and should have the ability to be lowered from and drawn up to an airplane without performing dangerous oscillations. The size and weight of the device were to be kept to a minimum. Specifically, it was required that the body could be lowered through a door 24 inches wide. A special $\frac{1}{2}$-inch diameter suspension cable weighing 0.185 pound per foot and a ball-bearing suspension pivot were supplied by the Bureau.

APPARATUS AND METHOD

A towed body was designed to meet the specifications (fig. 1). A full-scale model of the device was constructed from balsa wood about 2 inches thick, and the fins were laminated from a layer of plywood sandwiched between two sheets of balsa wood faired to an approximate NACA 0005 airfoil section, the ordinates for which are given on figure 1. The exact airfoil section used on the fins is not believed to affect the behavior of the body. The construction used was thought to represent approximately the weight of a thinner and denser material, such as plastic or plywood, that might be used to build the actual instrument container.

The suspension cable pivot supplied by the Bureau was similar to a gimbal frame and allowed the body to rotate freely in pitch, roll, and yaw. In actual application, it was considered desirable to place the pivot point at the center of gravity of the body. In order to provide stability in roll, the component allowing freedom in roll was removed, and, the cable for 6 inches above the pivot was made rigid by surrounding it with a piece of steel tubing.

Angular deviations in flight were measured by taking pictures with an 8-millimeter movie camera mounted in the nose of the body behind a plexiglass window. A timer in the airplane, connected to the solenoid-operated shutter of the camera through conductors contained in the cable, tripped the shutter at $\frac{1}{2}$-second intervals.

The weight of the body complete with camera and a small amount of ballast was 25 pounds. A photograph of the body is shown in figure 2. The installation of the camera in the nose is shown in figure 3.

The flight tests were made by lowering the device from a rack (fig. 4) beneath the cabin door of a small twin-engined, low-wing cabin monoplane. A hand-operated reel was employed to let out and take in the suspension cable. The cable was believed to be located outside the slipstream of the propellers except perhaps for the first few feet of its length.

RESULTS

The first flight yielded no photographic records, but it was found that the body could be lowered from and drawn up to the rack without difficulty. The device was observed to ride up at an angle about 30° from the vertical on this flight. Examination of the fins revealed that they were warped. For this reason, a small tab, shown on figure 2, was added to the trailing edge of the fin and offset slightly to counteract the fin angle. On subsequent flights the body hung almost vertically below the airplane. The tab is not believed to have any important effect on the stability of the body.

Records were obtained on the next two flights, one in rough air and one in smooth air. Approximately 100 feet of cable were let out on these runs. Typical sets of frames from the motion picture camera are shown in figure 5. Although haze prevented a clear picture of the horizon, objects on the landscape could be used as reference points to measure the motion of the body.

Time histories of the motion of the body in rough air are given in figure 6. In spite of the violent motions of the airplane, the body oscillated less than $\pm 2^{\circ}$ in pitch and yaw. The rolling motion was considerably greater, however. The body oscillated through an amplitude of about $\pm 10^{\circ}$. This oscillation is simply a side-to-side pendulum motion of the whole cable system. Inasmuch as the lateral motion of the body was probably not much greater than the lateral motion of the airplane itself, it is difficult to see how this amplitude could be reduced.

It will be noted that the equilibrium angle of roll of the body was not exactly zero. The body and cable were observed to ride off to one side slightly. This tendency was attributed to incorrect adjustment of the tab, and would not occur in a symmetrical body.

In smooth air, the body was very steady. As shown in figure 7, the amplitudes of the pitching and yawing oscillations were less than $\pm 0.4^\circ$, almost too small to detect. The rolling oscillation had an amplitude of about $\pm 0.8^\circ$. The body therefore meets the requirements for stability so long as the airplane flies steadily. Although measurements were made only with a cable length of 100 feet, the behavior of the body appeared to be essentially the same for shorter cable lengths.

The tension in the cable at 160 miles per hour was 55 pounds. This value compares with the weight of the bomb and cable of about 44 pounds. Because tests show that the air forces act almost normal to the elements of the cable, the tension would not be expected to increase much with increasing speed.

The angle made by the cable with the horizontal at its point of attachment to the airplane was not measured, but it appeared to vary between about 20° and 10° as the speed increased from 100 to 160 miles per hour. The cable thus trailed almost straight back at high speed. The body itself hung sufficiently far below its attachment to avoid coming into the wake or slipstream of the airplane.

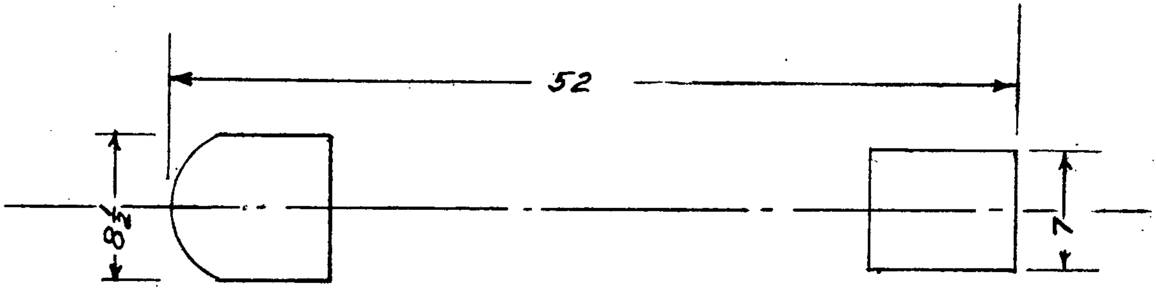
Because it is considered desirable to keep the span of the fins on the body as small as possible, further tests are planned in which the span of the fins will be reduced and the pivot point moved forward to preserve directional stability. The results of these tests will be presented at a later date.

CONCLUSIONS

1. The towed body desribed in this report was found to meet the requirements for stability. In smooth air, the amplitude of pitching and yawing oscillations was less than $\pm 0.4^\circ$, and the amplitude of rolling oscillations was less than $\pm 0.8^\circ$. These measurements were made with a cable length of 100 feet. The body performed no violent motions while being lowered from or drawn up to the airplane.

2. In rough air, the angles of pitch and yaw varied by about $\pm 2^\circ$ and the angle of roll about $\pm 10^\circ$.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., October 16, 1942



DIMENSIONS OF INSTRUMENTS TO BE CARRIED

ORDINATES FOR FIN AIRFOIL

% CHORD	UPPER AND LOWER
0	0
5	1.48
10	1.95
20	2.39
40	2.42
60	1.90
80	1.10
100	0.20

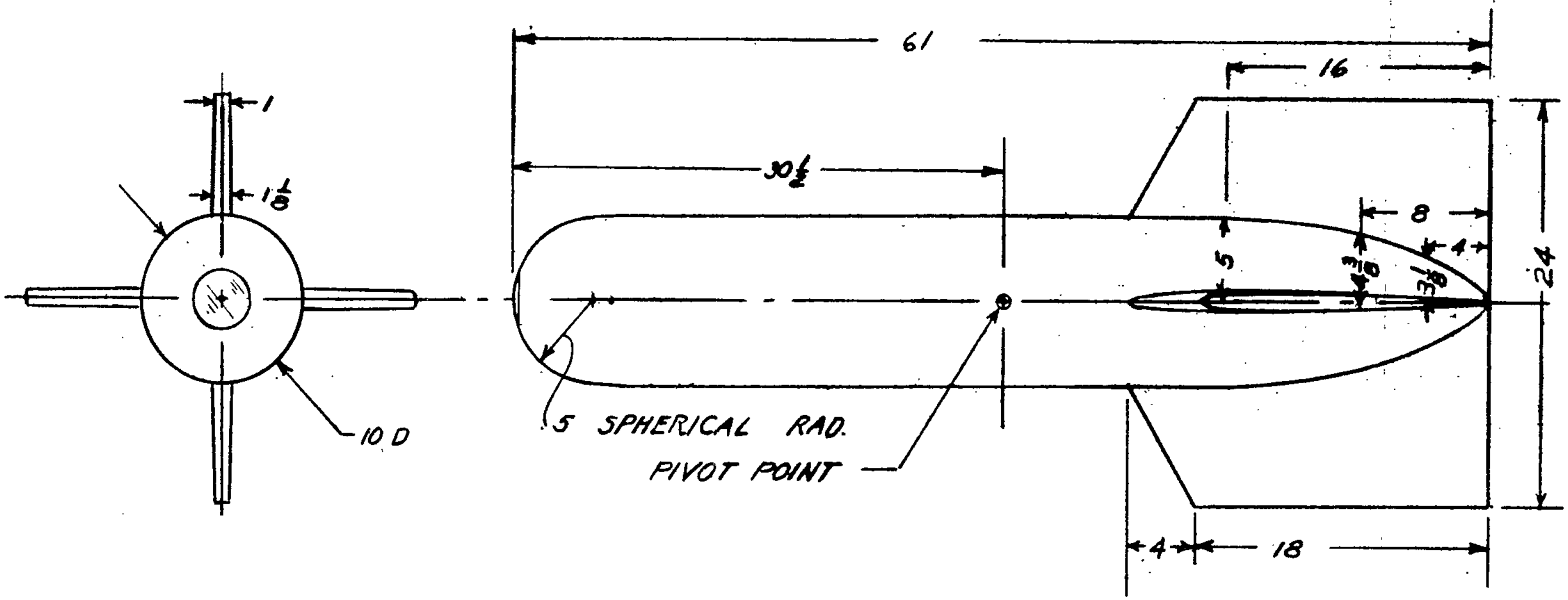


FIGURE 1. DIMENSIONS OF TOWED BODY

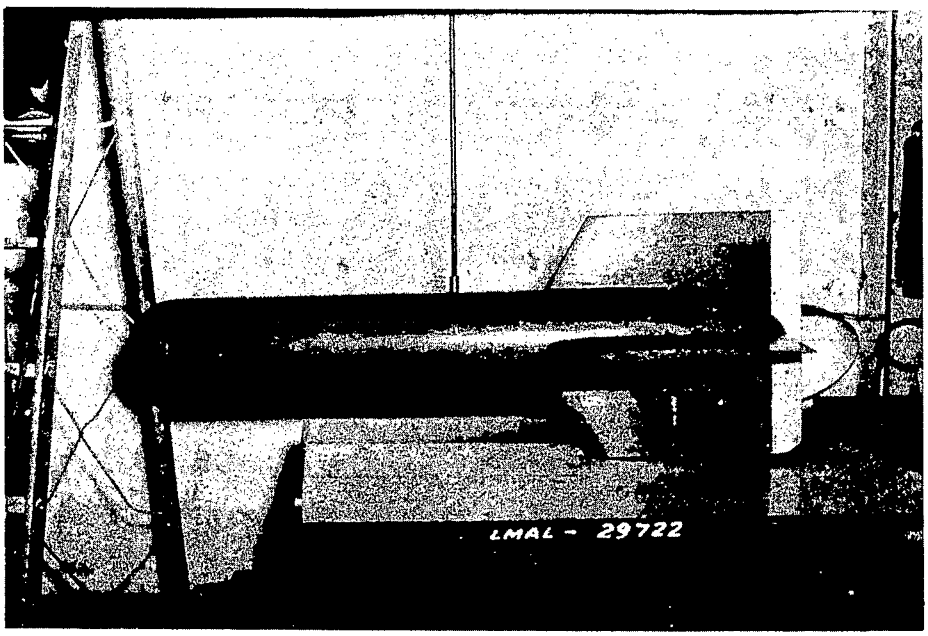


Figure 2.- Photograph of towed body.

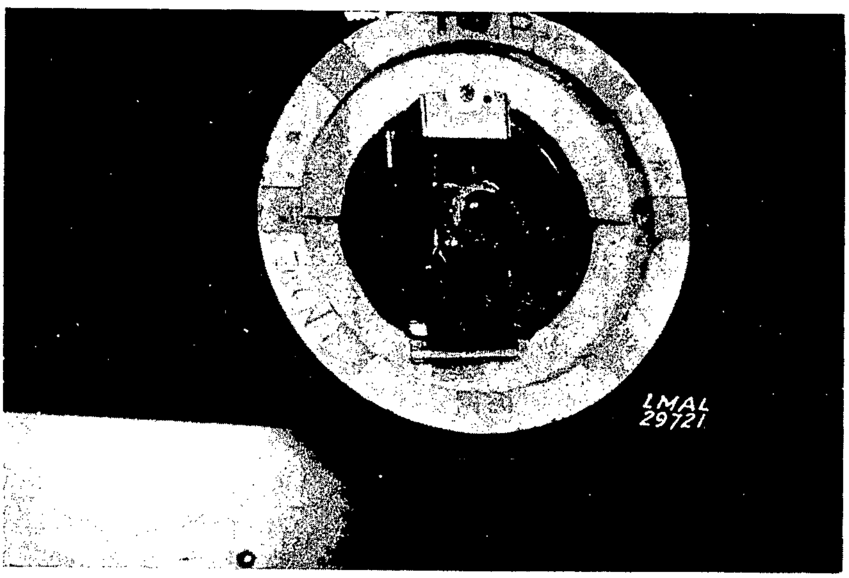


Figure 3.- Installation of camera in nose of towed body.

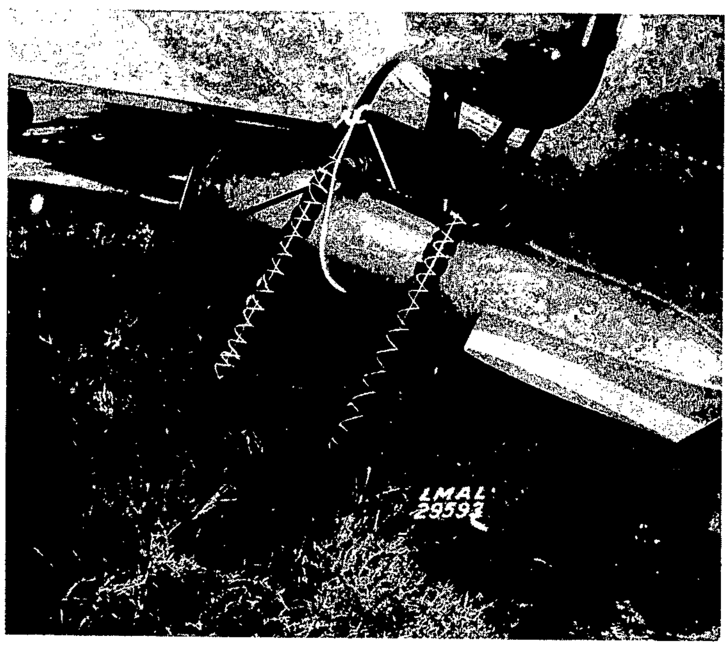


Figure 4.- Towed body mounted in rack on airplane.

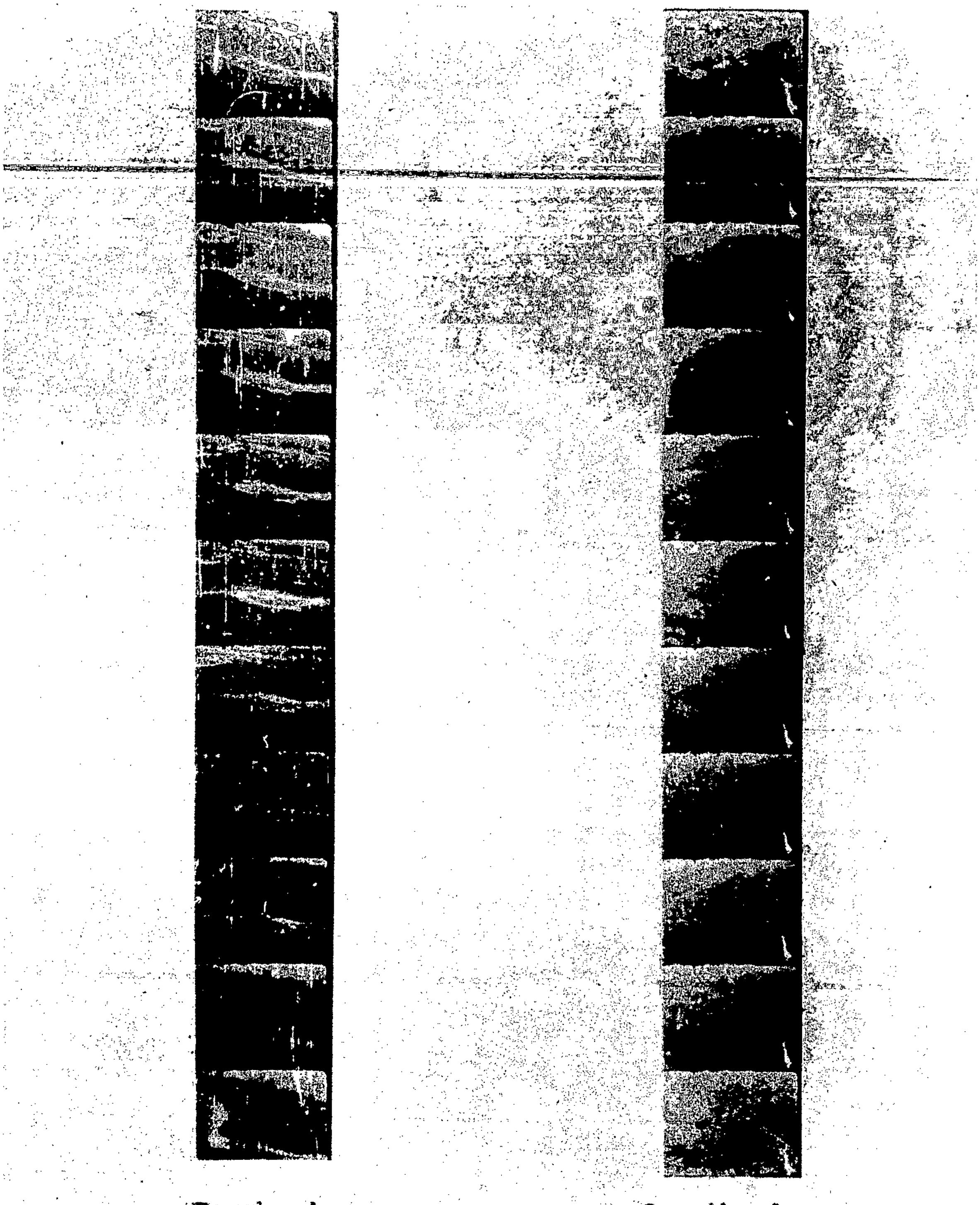


Figure 5.- Enlarged reproductions of typical records taken with 8 mm camera. Frames are at 1/2-second intervals.

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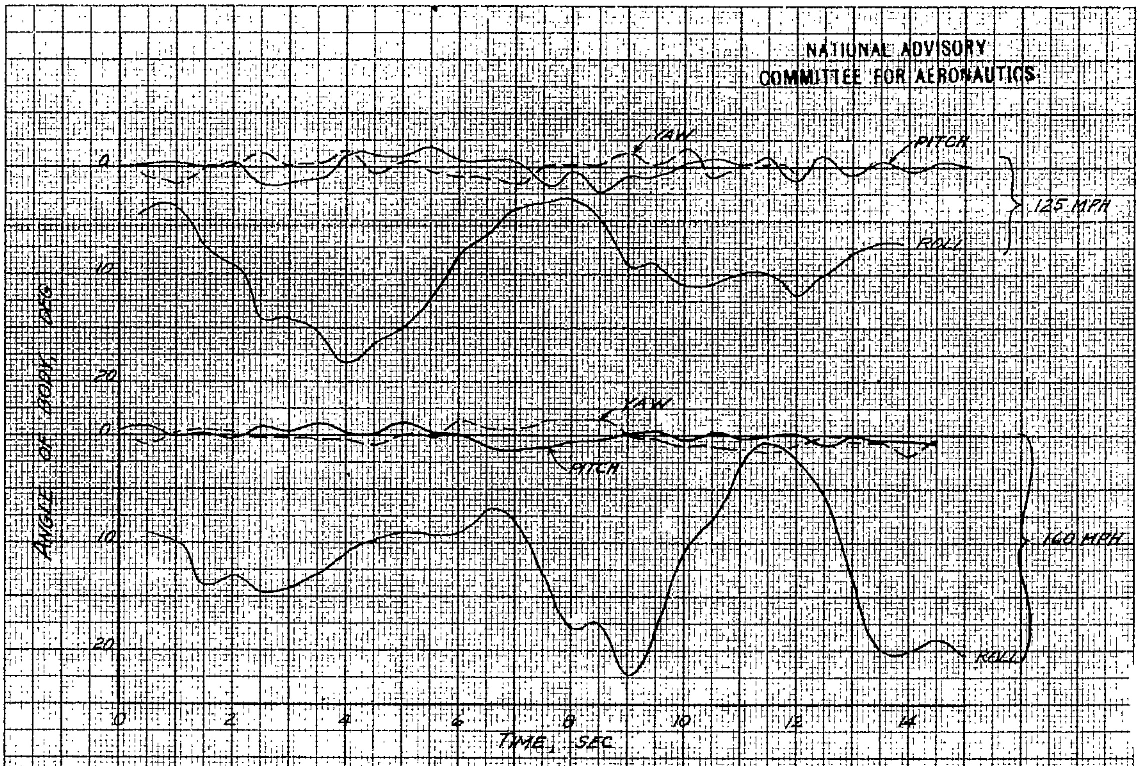

Figure 6. - Time histories of the motion of the towed body in rough air.

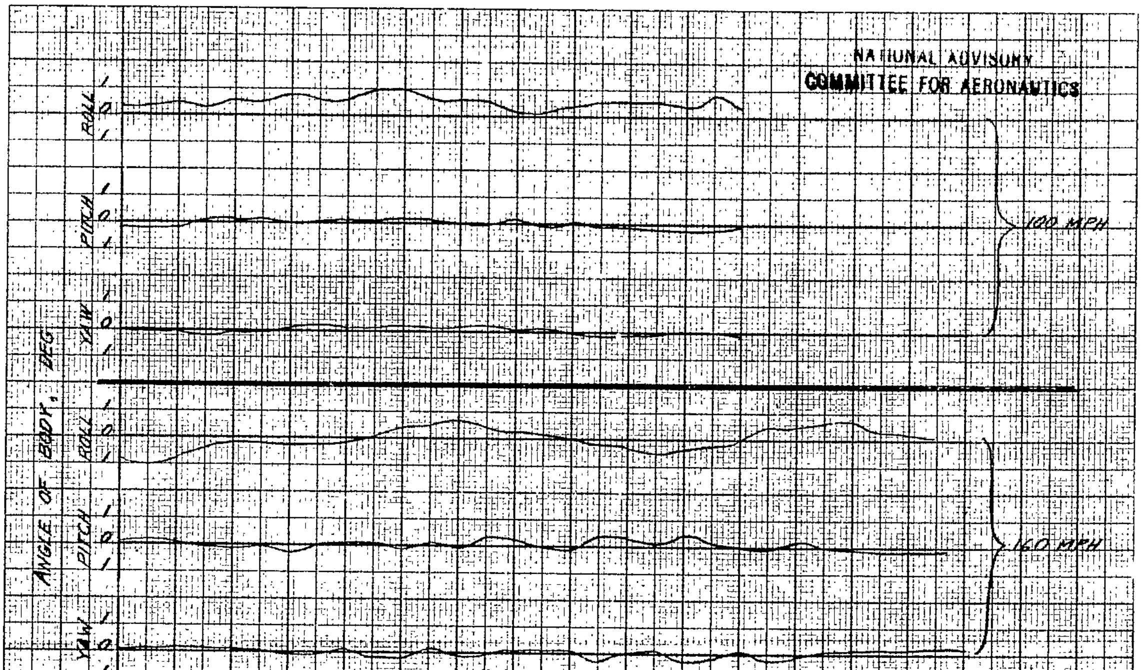

Figure 7. - Time histories of the motion of the towed body in smooth air.